UNITED STATES PATENT APPLICATION

FOR

METHOD OF IMPROVING FIELD EMISSION EFFICIENCY FOR FABRICATING CARBON NANOTUBE FIELD EMITTERS

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METHOD OF IMPROVING FIELD EMISSION EFFICIENCY FOR FABRICATING CARBON NANOTUBE FIELD EMITTERS

Field of the Invention

This invention relates to a field emission display, more particularly to a method of improving field emission efficiency of carbon nanotube field emitters by using a taping film.

Background of the Invention

Nanotube field emission display comprises an image pixel array formed on a substrate having conductive patterned thereon as a cathode, and a corresponding phosphor pattern array coated on an ITO glass as an anode. Each image pixel containing carbon nanotube (hereinafter called CNT) layer thereon as electron emission sources. The CNT layer made of a slurry consists of organic bonding agent, silver powder, and CNT, which having 5-100nm in diameter and 1000-3000nm in length. The principle of field emission is in terms of electric field accelerating cold electron which is emitted from the tip of CNT through vacuum space and bombards anode which is an indium tin oxide (ITO) substrate having phosphor pixel to generate fluorescence. By contrast to conventional cathode ray tube which is in terms of thermionically emitted electrons emerge from a tungsten wire, the field emission modeling has quite different fashion.

A typical field display schematic cross-sectional view is shown in Fig.1. The figure shows a conductive line array 20 coated on a substrate 10 by screen-printing a conductive slurry containing silver through a line-patterned screen. Thereafter, a CNT layer is attached thereon by screen printing a CNT paste through a mesh patterned screen to form image pixel layer30. The CNT paste consists of organic bonding agent, resin, carbon nano-tubes, and silver powder. After that the substrate is soft baked in an oven using a temperature of about 50 –200 ℃ to remove volatile organic solvent. Finally a higher temperature sintering process is carried out to cure the CNT on and to electric coupled with the conductive silver lines. In the sintering process, all of the organic bonding agent and resin are burned out.

The cost of above fabricating process is low and it is not a merely benefit. Field emission display can have very thin electron gun of only about 0.2mm in thickness. In addition, the size of planar area can have very flexible, it can be very small such as 1 cm^2 and can as large as several hundred centimeter square. The CNT-FED is thus a prominence for an ultra thin flat panel display. For a display, the stability and long life reliability are fundamental characteristics. However, as high as 10-100 mA/cm^2 in current density is a minimum criteria and the most critical characteristic for generating sufficient brightness and uniformity for a display. To approach such current density, the lower intensity electrical field is preferred. Preferably, it should be lower than 5 V/μm.

Since the electric property (current density vs. intensity of electric field) is predetermined by a number of exposed CNT, which should be

electric coupled with the conductive layer 20 of the cathode. However aforementioned CNT field emission device of prior art in general emits very low current density unless using extra processes and/or user high electric field intensity. Please refer to Fig.2, showing a curve 110 by using conventional process and another curve 120 in accordance with the present invention. In figure, the current density versus electric field is shown. The conventional process has a current density lower than 1 mA/cm^2 for intensity of electric filed of about 6V/μm. To achieve 10-100 mA/cm^2 in current density emission exerting a rather high electric field intensity is usually expected.

Thus, as acquired knowledge known by the inventor, none of issued invention discloses a CNT emission display, which can approach the goal of producing the critical current density in the electric field intensity as low as 6V/μm. U.S. Patent Number 5,616,368, issued to Jim et al, disclose a patent about field emission display. Jim et al proposed hat using activated ultra-fine diamond particulate as emission sources for field emission source can significantly improving the prior art of their patent. As stated in Jim's patent, ultra-fine diamond particulate has a low or negative electrical affinity, and thus can act as field emitter in low electric field. An electric field of more than 70V/μm is needed for typical p-type doped diamond substrate to generate an emission current density of 10 mA/cm^2. In Jim's patent, a field of about 12V/μm or even down to 5V/μm to achieve the minimum current density.

The method of Jim et al comprises following steps. First, diamonds, predominantly having maximum dimensions in the range of 5-10,000 nm

are prepared. Prior to paste the particulate emitters to the substrate, the ultra-fine particles are exposed in a plasma containing hydrogen at a temperature in excess of 300 °C. In order to minimize agglomerations of the particles during the plasma activating processing and in order to have relative uniform activation on major part of the exposed diamond surface, the particles in continuous motion by injecting high speed gas flow is performed. In addition, the diamond particles have less than 10 volume percent of graphitic or amorphous carbon phases. Thereafter the diamonds particles with bond agent are mixed and screen-print to a predetermined conductive trace containing substrate. Finally a sintering process at a temperature of about 500 °C is perform to form pixels.

As forgoing prior art, for CNT there is not available method present to improve the problem of the high electric filed needed except using the ultra-fine diamond particles. In addition, the method to alleviate agglomeration of the particles proposed by the prior art is before pasting on the conductive layer. Consequently, whether agglomerated again after slurry prepared and sintering process is not sure. Thus the present invention is to improve the CNT field emitter. Furthermore, CNT field emitter improvement by the present invention has lowed cost and easily to implement.

Summary of the Invention

The present invention is to propose a simple CNT field emitter forming method, which significantly improves the efficiency of CNT.

The present invention discloses a method of CNT emitter current density improvement by a taping process. The method comprises following steps. First of all, a conductive pattern coated on a substrate by screen-printing a conductive slurry containing silver through a patterned screen is carried out. Thereafter, a CNT layer is attached thereon by screen-printing a CNT paste through a mesh pattern screen to form CNT image pixel array layer. The CNT paste consists of organic bonding agent, resin, silver powder, and carbon nano-tubes. After that the substrate is soft baked by an oven using a temperature of about 50-200 ℃ to remove volatile organic solvent. A higher temperature sintering process, for example 350-550 °C is then carried out to solidify the CNT on and electric coupled with the conductive pattern. Finally, an adhesive film is closely attached on the cathode substrate and then remove the adhesive film away so as to remove those badly bonding CNT portion and to vertically pull up a portion of CNT which originally laid down on the surface after sintering. Consequently, the current density, brightness, and uniformity of the emitter sources are significantly improved.

Brief Description of the Drawings

The foregoing aspects and many of the attendant advantages of this invention will become more readily appreciated as the same becomes better understood by reference to the following detailed description, when taken in conjunction with the accompanying drawings, wherein:

FIG. 1 illustrates a schematic structure of CNT field emission

display.

FIG. 2 illustrates a comparison of current density versus electric field intensity performance for the CNT cathode substrate with taping and without taping.

FIG. 3 illustrates a SEM image of CNT cathode after sintering process without taping.

FIG. 4 illustrates a SEM image of CNT cathode after sintering process with taping.

Detailed Description of the Invention

The aforementioned fabricating process for a CNT field emission display descried in the background of the invention high electric field intensity is required to generate sufficiently current density. For ultra-fine particulate diamond, though the electric filed can be drastically down to an accept range, but complicate processes are demanded. Besides, the fine particles are processed though gas flow and hydrogen containing plasma. However, after screen-printing and sintering, none of any further improve method is promoted. The effect is expected to be discount and degrade the quality of the field emission device.

The present invention proposes a surface treatment with simple but can be available to improve forgoing issues.

The inventors investigated that the low current density for the conventional screen print CNT process is due to following reasons: One is due to some of the CNT emitter sources still not exposed but buried in the CNT layer, which do not have current density contribution. The other is

due to the fact that the upper portion of CNT layer on the conductive silver layer has a poor adhere quality. As a result, the portions of the badly attached CNTs are attracted to the anode and then damage the phosphor layer.

Hence, the inventors propose following processes.

In a preferred embodiment, the CNT layer formed is carried out as aforementioned background of the invention. After screen print, the conductive line array of about 50-150 μm in interval and150-300 μm each in width is formed. Each of the field pixel is about 0.02-0.09 mm^2 are formed. the soft baked temperature is about 50-200 ℃ to remove away organic volatile solvent. A taping process is performed by using adhesive film such as a tape with adhesive material thereon or polymer film with static electrical attractive material on the CNT substrate through a laminator to closely attach on the CNT layer and the adhesive film are pulled up and removed away. The process can remove some badly attached CNT. Some of the CNT buried in the CNT layer is also pull up to a proper direction.

Thereafter, a sintering process at a temperature of about 350-550 ℃, is performed. A taping process is done to remove a portion of poor attached CNT on the substrate. The taping process can apply by a laminator or by a rubbing process or a press print to closely attach the adhesive film to the surface of the CNT film. It is found the contribution of the taping process to the current density improvement after sinter is more notable then after soft baked. The taping process after soft baked is thus an optional process.

Fig.2 shows a comparison of curves 110 and 120 of current density vs. electric field intensity for a CNT field emitter formed by a conventional method without taping process and formed by the present invention (the conventional method but associate with taping process, respectively). With taping process, the current density comes up to over 10 mA/cm^2 for electric field intensity of about 5 V/μm. However, without taping process, the current density is still lower than 1 mA/cm^2 even for electric field intensity of about 6 V/μm. The result shows the present invention has protruding effect.

Fig. 3 shows a cross-sectional view image of CNT emitter pixel without taping process to the CNT cathode, investigating by scanning using electron microscope. Fig.4 shows a cross-sectional view image with a taping process to the CNT cathode. By comparing Fig.3 with Fig.4, the CNT layer for a taping CNT emitter pixel is thinner than that of without taping. It proves that a portion of the CNT layer with badly attached on cathode is removed though taping process. In addition, some of the buried CNT emitter sources can also be pulled up to a proper directionally.

The present invention provides following benefits:

(1) The current density of CNT emitter source can be significantly increase at low electric field intensity without complicated process but by a simple taping process.

(2) The taping process is a low cost and easier process, and no high accuracy instrument and complicated parameter are demanded..

As is understood by a person skilled in the art, the foregoing preferred embodiment of the present invention is an illustration of the present invention rather than limiting thereon. It is intended to cover various modifications and similar arrangements included within the spirit and scope of the appended claims, the scope of which should be accorded the broadest interpretation so as to encompass all such modifications and similar structure.